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NIF CAPSULE SENSITIVITY TO DRIVE ASYMMETRY

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We examine 300 eV ICF capsules with ablators of Ge-doped CH, and consider the 2-D parameter space of ablator thickness and DT-ice thickness. At each point in this parameter space, we optimize the drive for a low entropy implosion. At five points in this parameter space, we run 2-D sensitivity studies with radiation drive asymmetries with both constant and time-varying Legendre coefficient P_2, P_4, P_6, and P_8 to determine how much asymmetry the capsule can tolerate before the yield degrades substantially. We find that the thinner capsules with higher implosion velocities are more tolerant of drive asymetries.

I. INTRODUCTION

Proposed NIF ICF capsules are sensitive to asymmetries resulting from radiation drive and capsule imperfections. Capsule imperfections are amplified by the Rayleigh-Taylor and Richtmeyer-Meshkoff instabilities, and pose a risk at mode numbers up to about 100. Radiation drive asymmetries are also amplified by these hydrodynamic instabilities, and pose a danger at modes below 10. Previous work has mostly concentrated on quantifying the sensitivity to capsule imperfections[1]. Here we concentrate on characterizing the sensitivity to drive asymmetries.

We examine 300 eV ICF capsules with ablators of polyimide and Ge-doped CH. This capsule has a 2-D parameter space of ablator thickness and DT-ice thickness. At each point in this parameter space, we optimize the drive for a low entropy implosion. At five points in this parameter space, we run 2-D sensitivity studies with radiation drive asymmetries of constant Legendre coefficient P_2, P_4, P_6, P_8, as well as $-P_2$ through $-P_8$, to determine how much asymmetry the capsule can tolerate before the yield degrades substantially. We also examined the effect of time-varying asymmetry on the 85 eV foot and at the peak of the drive. This exercise gives us contours of capsule sensitivity to drive asymmetry. When combined with contours of sensitivity to the Rayleigh-Taylor instability, we can choose the capsule dimensions that optimize overall robustness. This information will help determine which capsule and ablator we choose for our NIF ignition capsule.

II. RESULTS

Figure 1 shows the parameter space of ablator and DT ice thickness, with contours of peak implosion velocity and yield. We picked five points in this parameter space for further study, with ablator/ice thicknesses of 150/80, 150/105, 160/90, 175/80 and 175/105 μm. Each capsule has an optimized drive that keeps the fuel on a low adiabat. We drove each capsule with a constant asymmetrical flux, increasing the asymmetry until the capsule failed to ignite. In each case, the asymmetry had the form of one of the Legendre polynomials P_2, P_4, P_6 and P_8. Figure 2 and Table I below show the location of the half-yield failure point for the 5 capsules. Figure 3 shows the same data, but plotted vs. peak implosion velocity, defined by the square root of twice the maximum kinetic energy of the fuel divided by the fuel mass. Note that the sensitivity is largely a function of implosion velocity. This is because a higher implosion velocity increases the margin for ignition, allowing the capsule to tolerate a greater distortion of the fuel at ignition time. Figure 4 show contours of fuel density close to the time of peak fuel density for the case when the asymmetry is big

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[1] S.W. Haan, T. Dittrich, G. Strobel, S. Hatchett, D. Hinkel, M. Marinak, D. Munro, O. Jones, S. Pollaine, and L. Suter, "Update on ignition target fabrication specifications," *Fusion Science and Technology* **41**, 164 (2002).

enough to reduce the yield by about 50%, for the case of both positive and negative Legendre coefficients. Note that for P_2, the jets correspond to maxima of the drive, whereas for P_4, P_6 and P_8, the jets correspond to the minima of the drive.

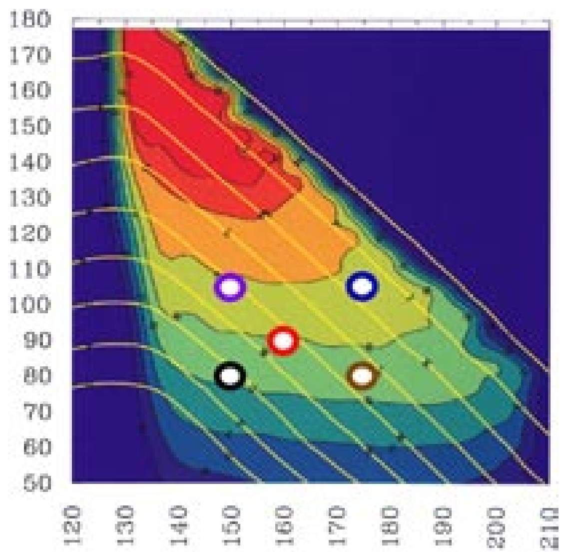

Figure 1. Parameter space of fuel thickness vs. ablator thickness, with 5 marked points studied in this paper. Contour lines are of peak implosion velocity, with higher values to lower left, and shaded regions are contours of yield, with higher values to upper left.

Table I: Maximum constant-asymmetry amplitude tolerated by capsule (%), and implosion velocity (km/s). Fuel and ablator thicknesses are in μm

Ablator	150	150	160	175	175
Fuel	80	105	90	80	105
V_{imp}	397	358	361	345	320
P_2	3.2	2.85	2.7	2.2	1.72
$-P_2$	4.0	3.5	3.0	2.4	1.9
P_4	3.5	3.2	2.6	2.3	0.6
$-P_4$	2.9	1.9	2.5	1.3	0.3
P_6	1.4	0.7	0.75	0.55	0.2
$-P_6$	1.1	0.7	0.7	0.55	0.2
P_8	1.7	0.5	0.9	0.6	0.11
$-P_8$	1.0	0.45	1.5	0.8	0.09

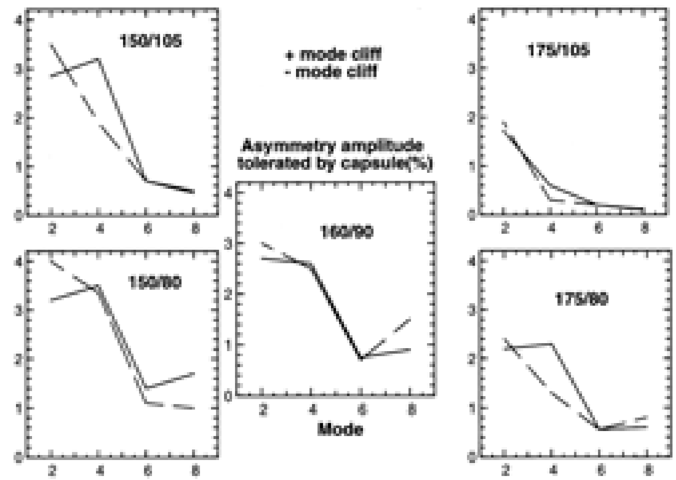

Figure 2. Location of half-yield cliff(%) for each of the 5 capsules for modes 2,4,6 and 8. Positive modes are solid, negative modes are dashed.

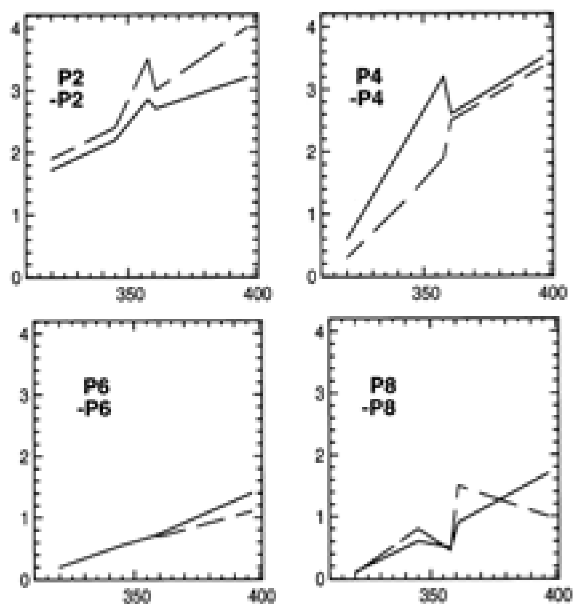

Figure 3. Location of half-yield cliff(%) for modes P_2 through P_8 (positive modes are solid, negative modes are dashed) as a function of peak implosion velocity.

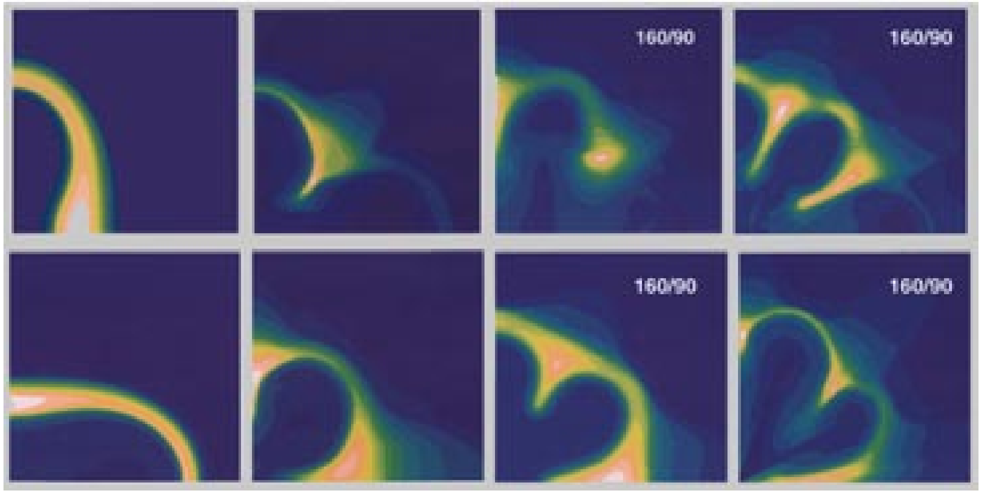

Figure 4 Density contours at time of peak density for 160/90 capsule. Top row, P_2, P_4, P_6 and P_8; bottom row, the negative modes -P_2, -P_4, -P_6 and –P_8.

We also ran capsules with time-varying asymmetries. For each of the five capsules, we applied a square pulse of 40% P_2 between 3 and 5 ns, followed by a square pulse of –40% P_2 between 5 and 7 ns, in order to test the sensitivity of the capsule to time-varying asymmetry on the foot, which lasts for about 9 ns. In all five cases, the capsule gave full yield. We did the same asymmetry perturbation at the time of peak drive, with a 1 ns square pulse followed by a 1 ns negative square pulse. The capsules are much more sensitive at this time, when the capsules are accelerating to their peak velocity. Table II below summarizes the location of the half-yield cliff for the five capsules, while Table III summarizes the location of the cliff for the capsule 160/90 for P_2, P_4, P_6 and P_8.

III. CONCLUSION

We examined five points in ablator thickness – fuel thickness parameter space for Ge-doped CH ablator ICF capsules. The thinner capsules with higher implosion velocity are more tolerant of drive asymmetries. Constant asymmetries of P_2 and P_4 cause the capsule to fail when the amplitudes exceed about 3%, while constant asymmetries of P_6 and P_8 cause the capsule to fail when the amplitudes exceed about 1%. Time-varying asymmetries on the foot of the drive have almost no effect, but variations at the time of peak drive will prevent ignition if the peak-to-peak amplitude swing of P_2, P_4, P_6, and P_8 exceeds 36%, 50%, 16% and 5%, respectively.

Table III: Location of half-yield cliff for capsule 160/90 for both foot and peak of drive for time-dependent P_2, P_4, P_6 and P_8

Mode	P_2	P_4	P_6	P_8
Foot	>40%	>40%	>40%	>40%
Peak	18%	25%	8%	~2.5%

Table II: Location of half-yield cliff for the five capsules for time-dependent P_2 and P_4 at peak drive, and imte-dependent P_2 on the foot of the drive

Time	mode	150/80	150/105	160/90	175/80	175/105
Foot	P_2	>40%	>40%	>40%	>40%	>40%
Peak	P_2	16%	10.8%	18%	18%	16.7%
Peak	P_4	26%	16.5%	25%	25%	14%

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